ECE Team 8 / ME Team 29
Strength Assisting Orthotic

Sponsor: Dr. Michael Devine
Advisor: Dr. Pat Hollis
Professor (ECE): Dr. Jerris Hooker
Professor (ME): Dr. Nikhil Gupta

Power-Flex Industries Team Members:
Ryan Whitney - Team Leader, Financial Lead
Derek Pridemore - Web Designer, Historian, Co-Lead ECE
Robert Slapikas - Assistant Team Leader, Lead ME
Jared Andersen - Co-Lead ECE
Donglin Cai - Co-Lead ECE

3/31/16

Project Overview

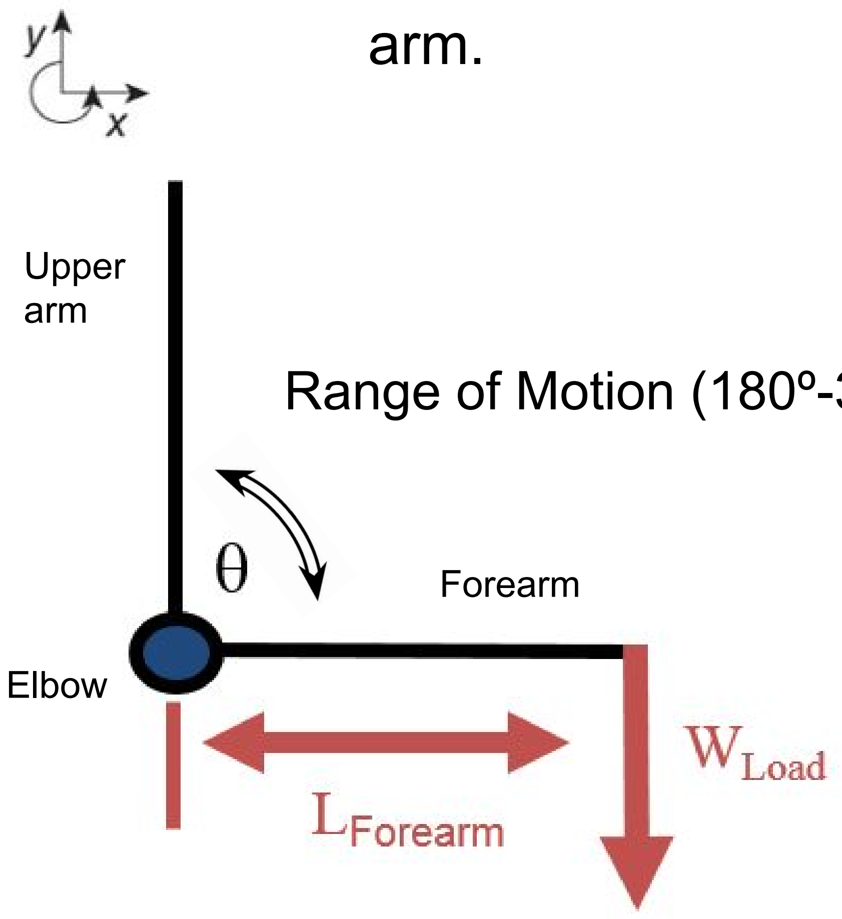
- Purpose: to design and build a powered orthotic arm.
- An orthotic is an artificial device that is used to increase bio-mechanical efficiency.
- Potential markets:
  - Healthcare
  - Inventory management
  - Military

Goals

1) Provide a strength-assisting powered orthotic that will make lifting heavy objects easier.
2) Increase endurance for holding said objects, using a form of actuation to mimic muscles and a frame to add structure.
3) Lift at least 10 pounds with just the power of the orthotic.
4) Give range of motion similar to a human arm.
5) Allow for a large user base.

Modeling the Load to be Lifted

To find the maximum torque needed, the maximum average forearm length will be used as the moment arm.



$\theta = 90°$

$L_{Forearm - max} = 52cm$

$L_{Forearm - min} = 38cm$

$W_{Load} = 21.lbs = 9.52\ kg$

Andersen

Backpack

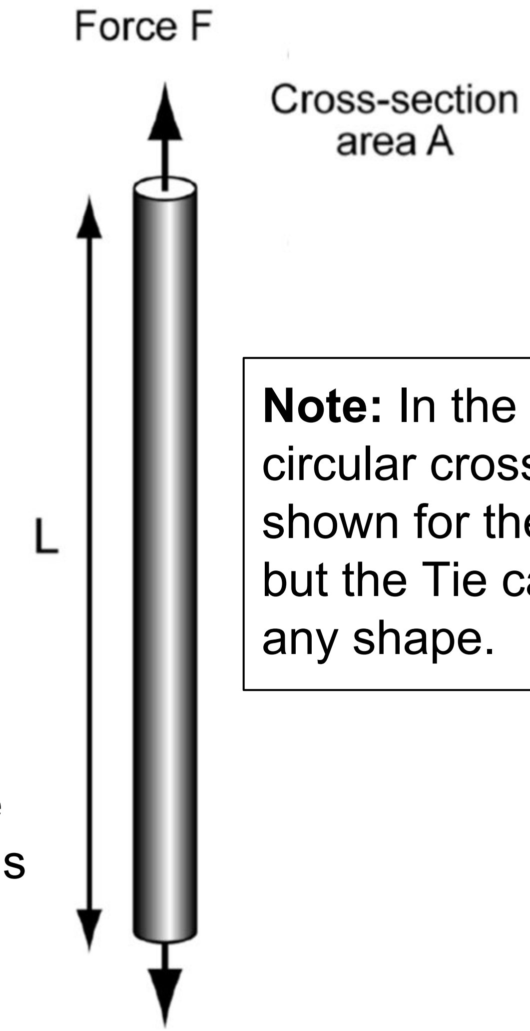
- Utilize both straps to spread weight evenly across the back
- Evenly spread moment of inertia
- Adjust straps so that the bag fits closely to the body and does not sit low below the hips
- Houses the microcontroller, motor driver, and battery.

Material Selection

For the general design of our orthotic we simulate the arm as a light, strong, stiff Tie rod when the arm is at 180 degrees to obtain the coupling equation.

$$\frac{E}{\rho} = \left(\frac{L}{\delta}\right)\left(\frac{\sigma_y}{\rho}\right)$$

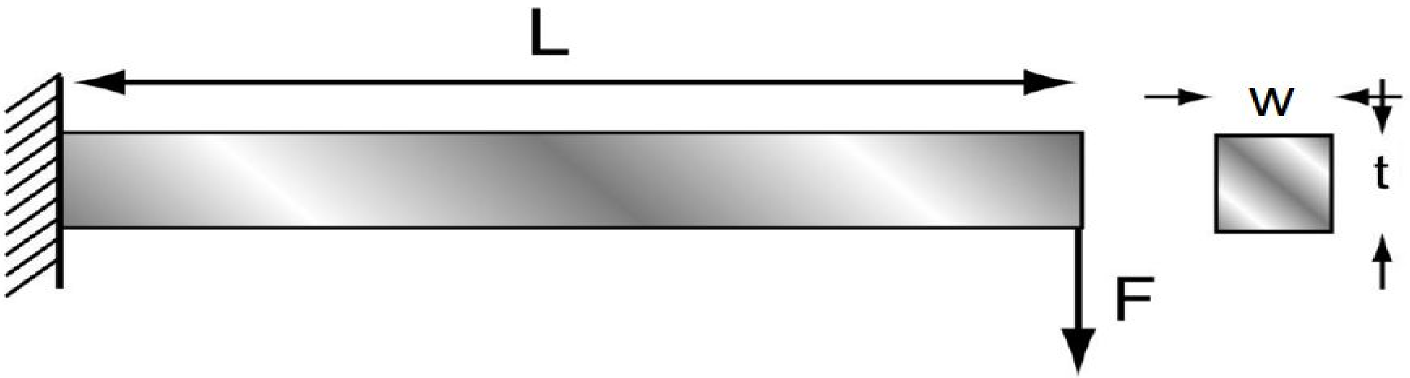
Where E is the young's modulus, ρ is the density, δ is the deflection of the tie rod, σ is the yield strength for the material the tie rod, and L is the length of the rod.



Note: In the diagram a circular cross section is shown for the Tie rod, but the Tie can be of any shape.

Material Selection (cont.)

Also for when the arm is in movement we can simulate the arm as a light, strong, stiff cantilever beam which is end loaded and the thickness(t) of the beam is known to get its coupling equation.

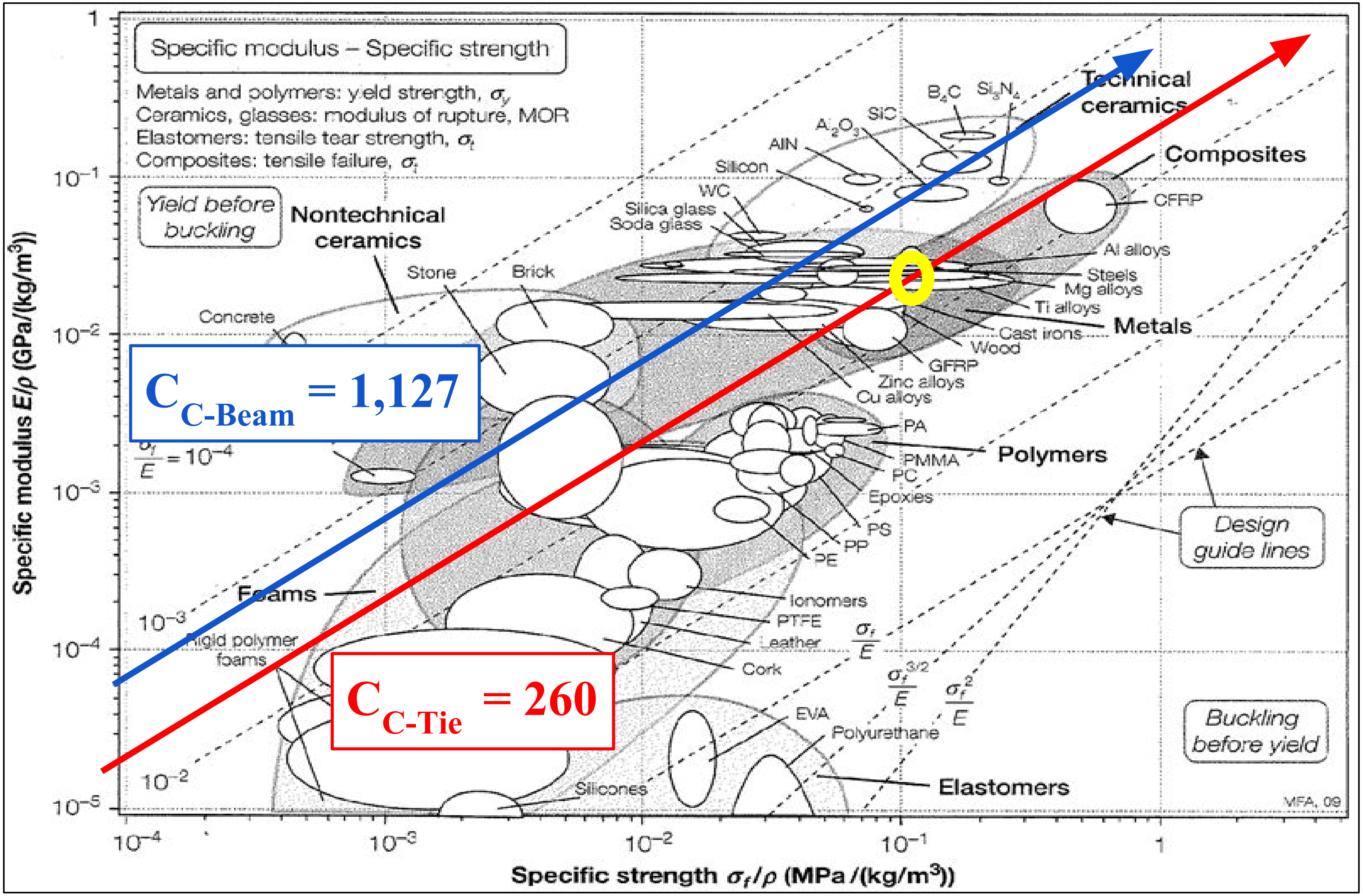


$$\frac{E}{\rho} = \left(\frac{4L^2}{6t\delta}\right)\left(\frac{\sigma_y}{\rho}\right)$$

Where E is the young's modulus, ρ is the density, δ is the deflection of the beam, σ is the yield strength for the material the beam, t is the thickness and L is the length of the beam.

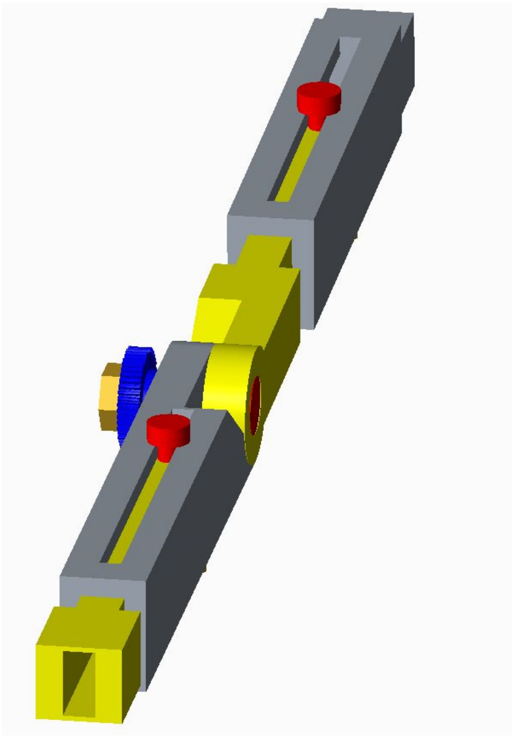
Slapikas

Material Selection (cont.)

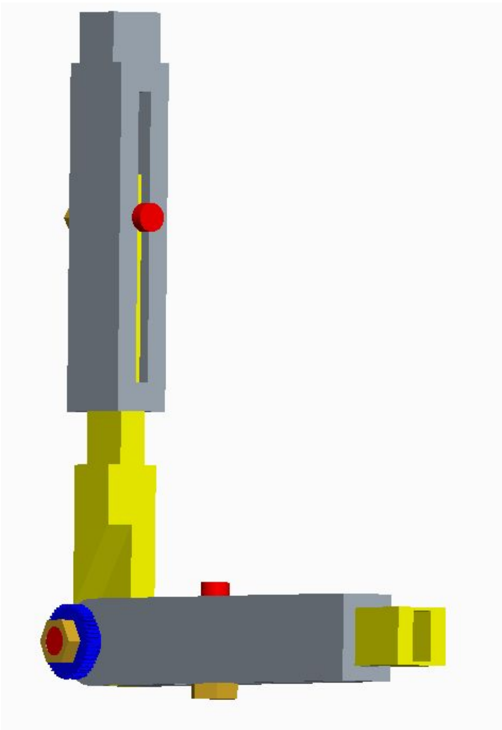


Slapikas

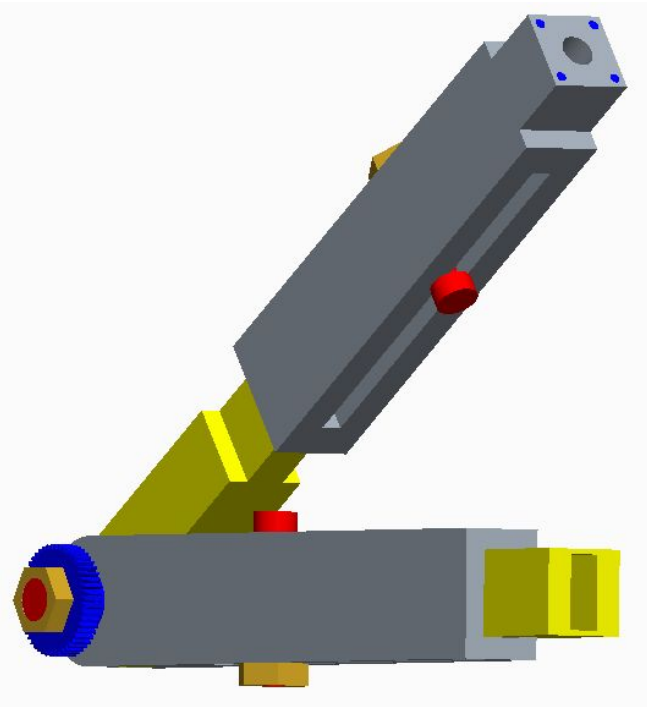
Frame - Circular Elbow Joint



Arm at 180 degrees.

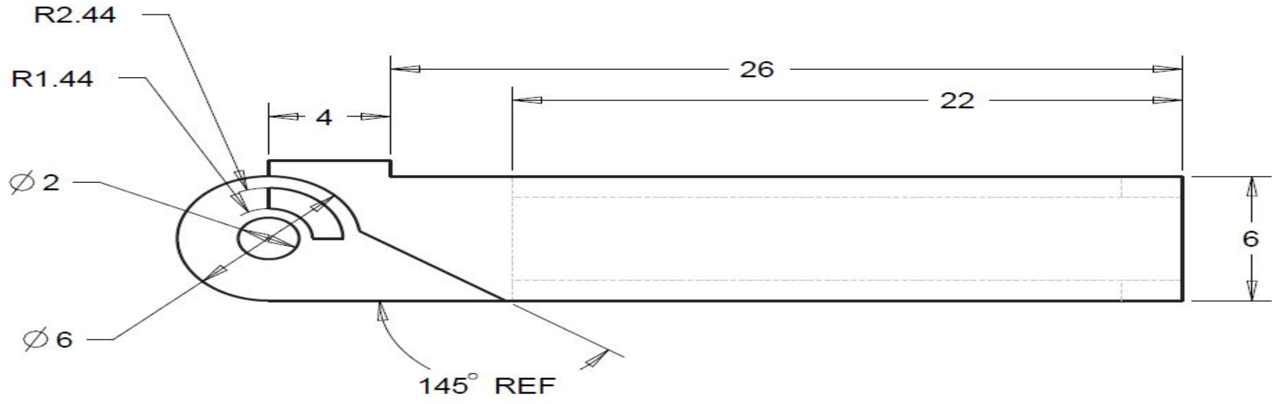


Arm at 90 degrees.

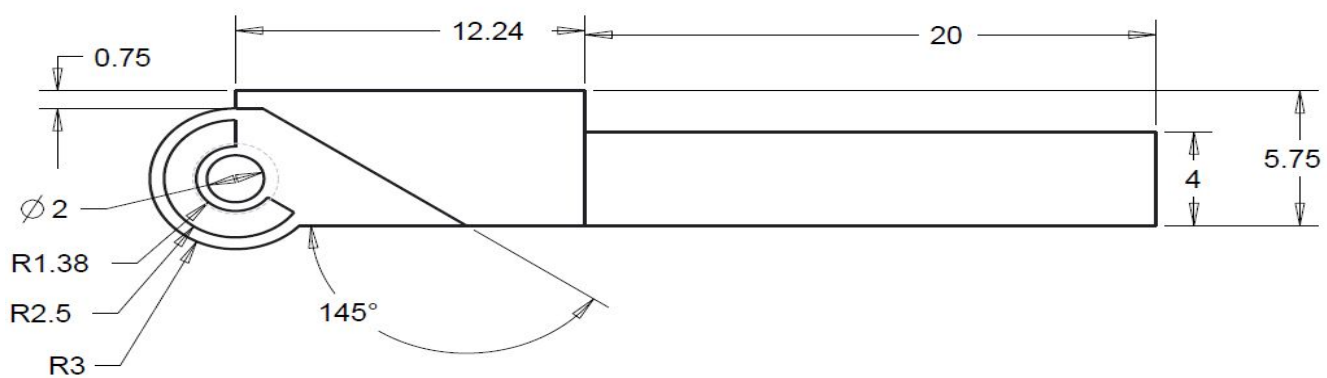


Arm at 35 degrees.

Frame - Circular Elbow Joint Pt. 2



Forearm Piece

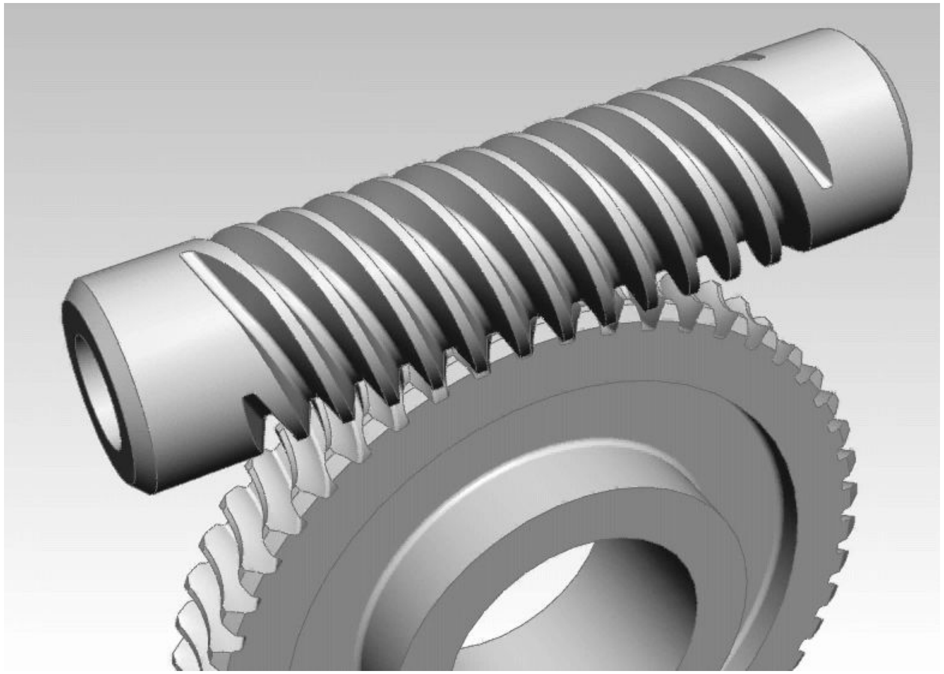


Upper Arm Piece

Worm And Worm Gear

We chose to apply torque through a worm and worm gear system for several reasons:

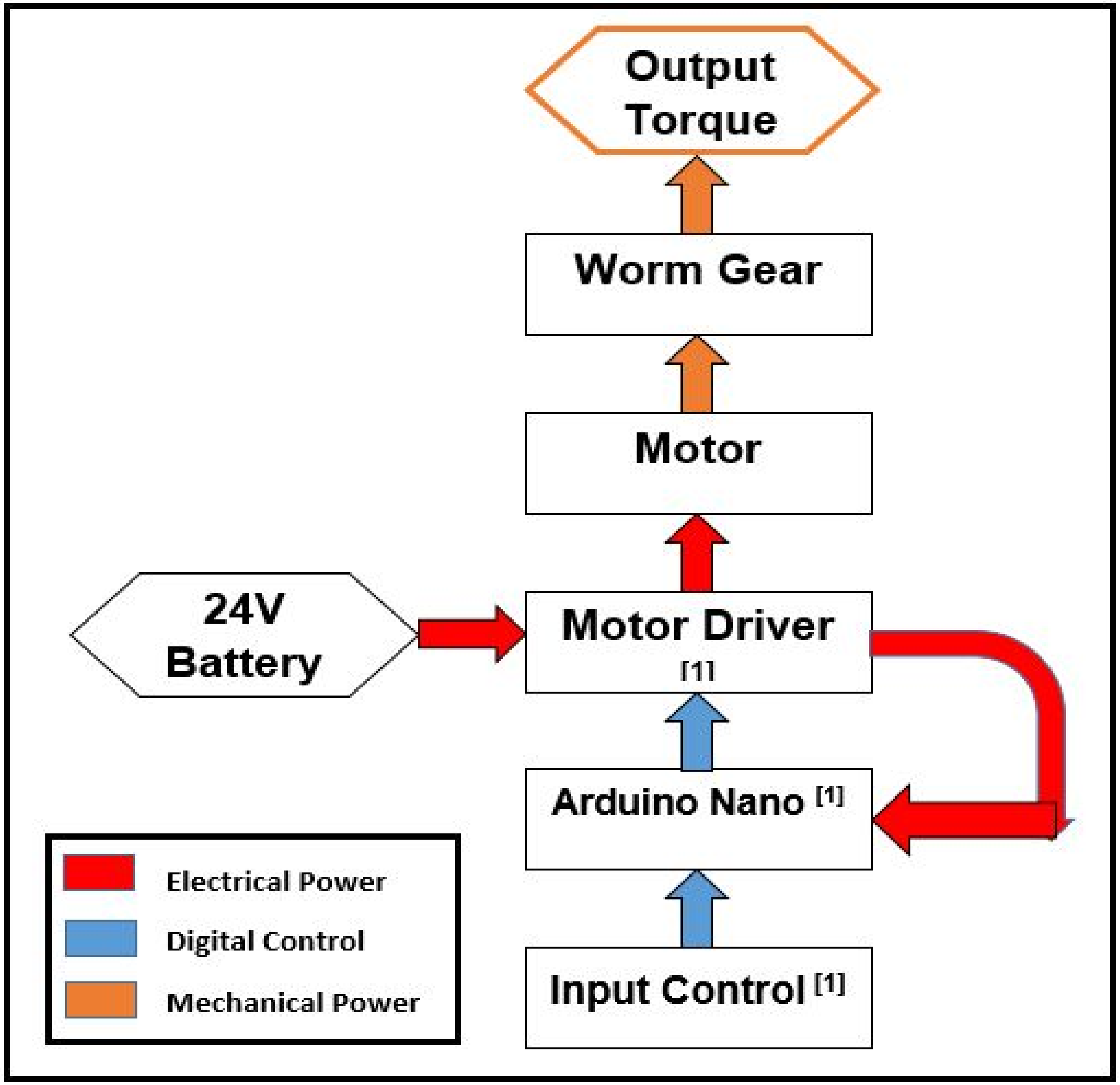
- Reduces motor speed
- Increases torque
- Easier to mount the motor and apply torque through the motor
- Locks the user's arm into position when the motor is not activated



Machining the Frame

- Frame is being machined in full with slight design modifications.
- Machining of the arm will be performed by the Physics Department machine shop.
- Back mounted frame has been obtained and modified with aluminum backplate for mounting the components not being directly mounted on the arm frame.

Upper Level System Diagram



[1] Indicates presence of a safety mechanism

Types of Electric Motors

Brushless Motor

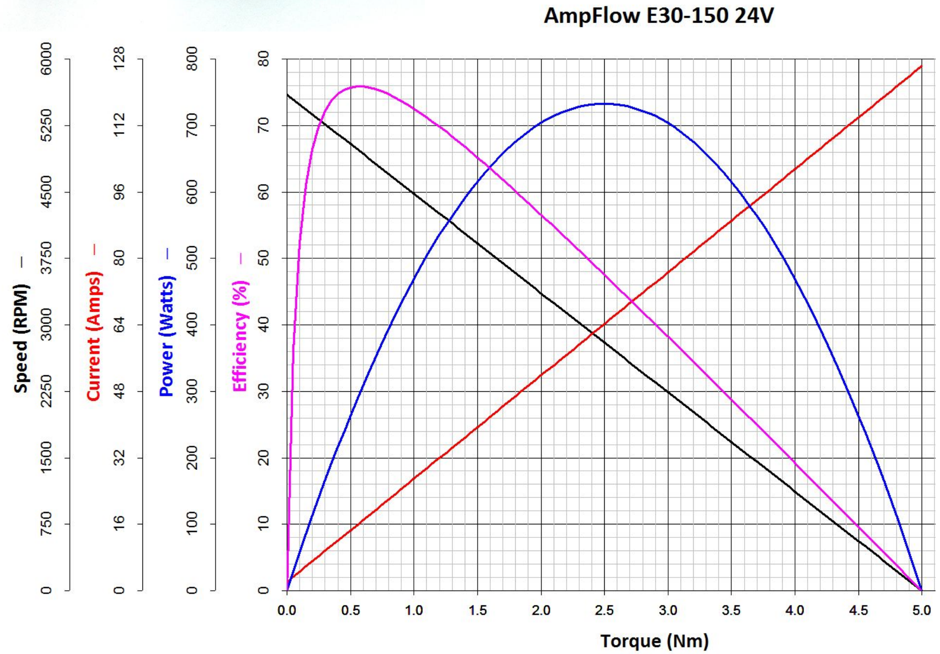
- DC Brushless
  - Higher efficiency due to no loss of energy from friction
  - A lower EF and RF noise
  - Output less heat
- Pancake Motor
  - Designed to be flat, use windings around a disc to provide the EM field.
  - The design allows for the motor to be much more compact than other motors
  - Need to be used at > than 40 kHz due to decreased induction
- Brushed DC Motor
  - Moderate level of control
  - Slower, so more torque
  - Rotates continuously

Pancake Motor

Brushed DC Motor

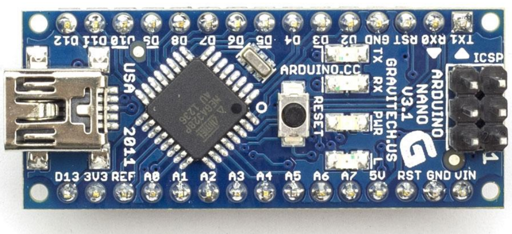
Motor Choice - AmpFlow E30-150

- Brushed DC Motor
- Stall Torque (Nm)
  - 5.014
- Max Rpm
  - 5600
- Operating Point
  - .95 Nm
  - 1450 rpm
  - 20 A
  - 24 V peak, 7.73V average
- Price
  - $79



Electronics Selection

- Motor Driver - SyRen 50
  - 50 amp continuous current rating
  - 100 amp peak current rating
  - Integrated thermal and adjustable overcurrent protection
- Microcontroller - Arduino Nano
  - Breadboard-friendly development board
  - Simple, cheap, effective



Pridemore

Budget Analysis

Budget for the project is **$1,400**.

Part	Cost of Design
Arduino Uno Nano	$8.88
DC Voltage Step Down Regulator	$8.36
AmpFlow E30-150 24V	$79.00
Driver Board	$119
Aluminum	$470
24V Battery	$83
Push Buttons	$4
Worm Gearset	$92
Back Mounted Frame	$100
Total Cost:	$964.43
Money Leftover	$435.57

Final Tests

Usage tests:

1. Running arm under no load to test strain on the motor.
2. Running arm under half load to test strain on the motor.
3. Running arm under full load to test strain on the motor.

Exertion of the motor will be calculated using the average current consumption.

Safety Analysis

- Potential Problems
    - Motor Overloading
    - Battery Overloading
    - Driver Overloading
    - Movement too fast/slow
    - Movement of arm outside of designated parameters
- Solutions
    - All tests performed in fire-resistant environment, with fire extinguishers present
    - Meticulous testing of set up under multiple test conditions to simulate different use cases
    - Multiple failsafes on multiple levels to ensure immediate shutdown upon abnormal operating conditions
- General Safety Protocols
    - At least three testers present during mechanical tests: one to perform, one to man the power switch, one additional to help the tester if necessary
    - At least two testers present during electrical tests: one to perform, one to man the power switch

Whitney

Conclusion

- Construction of the mechanical drive is complete.
- The electromechanical systems are complete.
- Machining of the prototype is almost complete.
- Final design of the prototype is complete.
- Safety clearance for human use is processing.

Questions?

[1] Breg Inc., 'Aligner PHX Humeral Fracture Brace', 2015. [Online]. Available: http://www.breg.com/products/fracture-bracing/aligner-phx-humeral-fracture-brace. [Accessed: 14- Nov- 2015].

[2] Amazon.com, 'Turnigy Heavy Duty Series 4000mAh 6S 60C - 120C Lipo RC Battery

', 2015. [Online]. Available: http://www.amazon.com/Turnigy-Heavy-Duty-4000mAh-60C/dp/B01A07QMUE/ref=sr_1_16?ie=UTF8&qid=1455775966&sr=8-16&keywords=6s+lipo. [Accessed: 18- Feb- 2016].

[3] Amazon.com, 'SyRen 50A Regenerative Motor Driver: Electric Motor Controls: Amazon.com: Industrial & Scientific', 2015. [Online]. Available: http://www.amazon.com/SyRen-50A-Regenerative-Motor-Driver/dp/B00CJ0BEE0/ref=sr_1_3?ie=UTF8&qid=1412717255&sr=8-3&keywords=syren%20dimension%20engineering. [Accessed: 15- Nov- 2015].

[4] Arduino.cc, 'Arduino - AnalogWrite', 2015. [Online]. Available: https://www.arduino.cc/en/Reference/AnalogWrite. [Accessed: 18- Nov- 2015].

Whitney